B69 01012

BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

SUBJECT: A Typical Earth Resources Aircraft Test Flight - Case 630

DATE: January 9, 1969

FROM: B. E. Sabels

ABSTRACT

Participation in earth resources sensor aircraft missions helps to assess the role of man and how best to develop automated sensor systems for earth orbital space missions. This purpose is illustrated by a description of the MSC aircraft mission 78 over Sonora Pass, California, on August 26, 1968.

As of now, earth resources sensor experiments require considerable participation of man as navigator, technician, decision maker, and ground calibrator. Present test site overflights with MSC aircraft involve a lot of time, manpower, equipment weight and size, all of which must be reduced significantly for high altitude and space craft sensing.

(NASA-CR-104006) A TYPICAL EARTH RESOURCES AIRCRAFT TEST FLIGHT (Bellcomm, Inc.) 16 p

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MEMORANDUM FOR FILE

INTRODUCTION

This writer participated in a part of flight mission 78 over Sonora Pass and Mono Lake, California, in order to assess the role of man in low flying remote sensor missions. This insight is expected to help us understand how best to develop automated high-flying and space sensor systems for earth resources.

Mission 78, Sonora Pass-Mono Lake, California, was flown out of Moffett Field, California, on August 26, 1968, by the NASA-MSC P3A aircraft. Test objective was to prove the feasibility of sensing the geological composition of a variety of terrain types with the newly developed three instrument IR pallet and data system. Principal investigator of the project is Dr. R. J. P. Lyon, Stanford University. The aircraft and a crew of fifteen men arrived from MSC on August 25, and on the same day a ground crew of twelve moved to the test sites in the Sierra Nevada from the University of Nevada at Reno. The locations are shown on the index map, Figure 1.

The Mission 78 is part of the NASA-MSC Earth Resources Aircraft Program that has the primary objective to fly remote sensing equipment over several dozen earth resources test sites, to take data as requested by principal investigators and to furnish the data for study. So far, two aircraft have been employed for this purpose, a Convair 240 and a Lockheed Electra P3A.

In the following, a description of the aircraft and of the flight on August 26 will be given.

THE AIRCRAFT AS A SENSING PLATFORM

1. Equipment

Figure 2 depicts the NP3A aircraft and all the primary and auxilliary sensors that will be installed as of January 1, 1969. Primary sensors operated during Mission 78 on August 26 were two RC8 metric cameras (black-white and color infrared), an RS-7 infrared imager, infrared spectrometer, infrared radiometer, and boresight camera. Supporting equipment were hygrometer, temperature probe, liquid water detector, and navigational equipment including air-to-ground radio. A multispectral Hasselblad camera cluster was operated for testing purposes. A more detailed list of sensors used and their specifications is given in Table 1.

2. Personnel

In flight, the aircraft was manned by a crew of 15 of which two persons were observers. Figure 3 depicts the location in flight of the two pilots and one navigator, mission manager, principal investigator, 3 IR operators, one central data manager and three camera operators. Table 2 lists by name the participating personnel. Some of these were located on the ground, and, with support personnel, manned the ground sites to be overflown and took ground truth measurements and meteorological data from balloon borne equipment. They also provided ground-to-air communication and verified the position of the plane relative to the test site ground strip. Two people provided a radio link between the staging base and the field crew via two ham radio stations.

3. Preparations Before Flight Date

The mission which was devoted entirely to IR spectral sensing and spectral photography, had been carefully rehearsed and shaken down at MSC during two weeks of pre-flight testing. The development and procurement phase of that equipment, depicted in Figure 4, has taken at least two years.

4. Flight Operation and Test Sites

The total flight program for the Site 19, Sonora Pass, and Site 3, Mono Lake, overflights is given in Tables 3 and 4. The total flight data mileage requested by the P.I. was 98 and 76 miles, respectively. Operational complexity is caused by the number of passes (26 and 26, respectively) and the varying flight altitudes, between 2,000 and 8,000 feet over site. One typical flight cycle consists of the following:

As soon as visual contact with the ground crew is made, direct radio contact is commenced. The pilot aligns the aircraft with the test site markers, white canvas crosses, using a geologic map on which are plotted the desired flight lines. (At night, generator-operated spot lights are used on the ground to mark the flight strip). He completes his corrective maneuver rapidly because the ground ahead of the aircraft disappears from view at a distance of about one mile. During the traverse of the last approach mile, lasting 15 seconds, several preparatory procedures go on. The operations manager goes through a countdown sequence. The ground crew issues radio instructions to the pilot guiding the plane onto the test strip. This is a critical operation because the spectrometer field of view is only 0.4 degrees in diameter, corresponding to 10 feet on the ground. The IR team turns on the sensors and exposes the IR standards. The data manager observes that all 26 data channels operate properly. The camera crew, having manually removed the cover of the objective lens and inserted the filters required for the existing light level and altitude, sets shutter speeds and f stops and adjusts the exposure rate based on V/H, so that 60% stereo overlap is achieved, as requested by the P.I.

One IR scan of 1/7 second, covering the spectral range from 6 to 13 microns, is performed while the plane covers about 40 feet of ground, with a swath width of 10 feet from 2,000 feet altitude. Thus, the ground coverage of the spectrometer at 2,000 feet corresponds roughly to the coverage of one freight car per scan. Subsequent scans add up to a coverage resembling a freight train oriented parallel to the course of the aircraft.

At the end of the countdown, the plane enters the test strip, and all sensing systems are turned on. The camera performance is monitored from the camera control console in the back of the plane.* The IR engineer checks visually that the spectral scans conform with expectations, and that natural standards such as water bodies and snow banks that lie in the course of the traverse are identified properly. For the latter task he consults the IR image provided by the RS7 imager. He also makes sure that the bore-hole camera operates properly. The data engineer monitors the recording of all data, including all intercom voice communication and incoming radio, on the central data tape. The present author looked through the camera windows in the bottom of the plane and was impressed that course and countdown hit the marks precisely. The choice of the test site became obvious as about ten grossly different rock zones, ranging from acidic rhyolite to basaltic rocks, in addition to zones of snow, water, and some vegetated spots passed below the plane. By and large, vegetation is sparse or absent at this elevation, consisting of conifers, brush and grass. The 6-13μ spectrum displayed on the oscilloscope changed in shape and intensity so significantly that one could identify the qualitative variations by mere observation. The importance of bore-hole camera and IR imager support for the identification of the spectra becomes quite apparent. After about 45 seconds the 3 mile course was completed, and the plane turned around, and the systems were put through the post-flight calibration sequence. Air temperature and liquid water content near the plane were recorded on the plane while the ground crew took the measurements on the ground. A tethered balloon carrying meteorological equipment provided some data from the atmosphere up to 1000 feet above ground.

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* Figures 5 and 6 depict the IR pallet monitoring equipment and camera monitoring panel.

On this flight the 26 passes were not completed. First, a gyro stabilization circuit for the IR RC 8 camera fell out as indicated by a warning light. One camera technician climbed into the pressurized bay and replaced a fuse, and the gyros were back in working order. The cause of fuse failure was not determined. During another pass a film magazine was expended as shown on the film indicator and had to be replaced. Two men removed the spent magazine and replaced it with a new one. After about a dozen runs had been completed, flown both 2,000 and 8,000 feet above ground, the spectrometer thermocouple indicator showed a lack of coolant, liquid helium, and the fast scan spectrometer terminated operation. The P.I. was informed, and he consulted with the mission manager and the flight commander as to what alternatives could be taken. The equipment is not accessible in the unpressurized area, and helium cannot be recharged in flight. Operational alternatives were cancellation of the mission for the day, return to Moffett Field for helium recharge and completion of the mission during the favorable weather, or continuation of the flight over the Mono Lake testsite using IR photography and IR imagery for hydrological studies. The latter choice was preferred, because of a good weather forecast for the following day. During the next hour, several flight lines over Mono Lake were selected and flown that were considered possibly of hydrological significance, and where spectrometry was not considered of utmost importance. About a dozen passes were made, which recorded hot spring activity and geothermal anomalies in rocks. It was obvious that the presence of the P.I. on the flight made the selection of an acceptable alternative possible, because no one else could determine which strips could be meaningfully covered without spectral data.

The plane reached Moffett Field at about 3:30 P.M. The IR pallet was recovered from the plane and wheeled into the hangar, and pumping of the dewars was resumed so that they would hold liquid helium on the following day's mission. (On the following day, the spectrometer performed without breakdown during the whole mission).

5. Preliminary Results

The IR spectra, IR photography, black-white photography and supporting data returned from the two flight days over Sonora Pass - Mono Lake were of excellent quality and quantity. It is noteworthy that three days had been set aside for the Sierra Nevada flight, and that only two days were needed, despite the spectrometer mishap. Some IR photography was lost in processing in the MSC photolab due to exposure to light.

6. Conclusions for Earth Resources Remote Sensing

The actual flight time over test sites requested for mission 78 was 174 line miles. The aircraft, having an operating speed of 240 mph, can fly this distance in less than one hour, yet twenty-six people were tied up for three work days to accomplish the task of gathering less than one flight hour's worth of data. One can say that 78 man days were spent for one net flight hour, or 3.6 man hours were spent per line mile.

The total weight of the limited scientific equipment flown on this mission is estimated at about 2000 to 3000 lbs. The total surface area of instrument panels monitored by nine operators and managers is about 50 sq. feet!

The first obvious impression derived from this flight is the complexity of preparation and execution, the size of the equipment and the number of personnel.

If one wants to execute a mission such as mission 78 by high-flying aircraft, the equipment monitoring prsonnel must be reduced by one order of magnitude (from 10 to 1), the total instrument panel surface by an order of magnitude (from 50 to 5 sq. ft.) , the weight by a factor of 1/2. The total number of man hours spent per flight mile will probably remain high, because of increased ground crew size. However, reduction of flight personnel will be made up by automation.

As an example of an IR experiment performed in space during the Gemini series, let us look at the D_4/D_7 IR experiment. The objective of D_4/D_7 was to measure IR spectra in the 1-5 micron range over a number of surface type areas. The two spaceborne instruments used had to be calibrated, directed, and operated in a scanning mode while the spacecraft traversed the target areas.

The Gemini D_4/D_7 IR spectrometer experiment required the attention of two crewmen. About 1000 net line miles were flown in 5 minutes, so that 0.0002 man hours were spent in space per line mile. There were no ground teams involved in D_4/D_7, who would have contributed of the order of 1 man hour per mile, in a situation comparable with mission 78. The weight of the D_4/D_7 equipment was about 50 lbs., another order of magnitude below mission 78. And the total surface area of the instrument panel consisting of five buttons covered about 0.04 square feet.

The experiment was only partly successful in that the interferometer lost its scanning capability during the mission at a random setting. The astronauts continued the measurements, however, after deciding that aerial scans at a fixed spectral setting were preferable to the termination of the experiment.

The following is concluded from this study:

1. Detailed earth-looking experiments, such as spectrometry of geological features, require considerable participation of man.
2. High resolution (small viewing angles) of the sensors requires high piloting and aiming skills in conjunction with ground control, without either of which the data acquired are worthless.
3. If the experiment (for example, IR camera) is accessible to manned operators, then the primary role of the operator is that of a mechanic. As such, he can alleviate partial systems failures, which otherwise cause the whole mission to fail.
4. If the equipment (for example, IR pallet) is not accessible to manned operators, in the unpressurized part of the P3A aircraft, then man's role is primarily that of a decision maker regarding the operation and regarding alternate modes of operation in case of partial systems failure. Without this adaptive capability, partial failures will tend to grow into complete failures.
5. Considerable reduction in weight and size is indicated for earth-looking (aircraft) sensors, in order to make them operable on high-flying aircraft and spacecraft. Each step involves about one order of magnitude of weight reduction. It does not appear wise to fly conventional aircraft equipment on high-altitude or spacecraft, as is occasionally proposed.
6. Fully automated, unmanned geological sensors appear to be in the remote distance, judging by the present pace of sensor evolution and progress.

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B. E. Sabels

Attachements
Tables 1-4
Figures 1-6

TABLE I. - SENSOR EQUIPMENT - LOCKHEED ELECTRA NP3A[a]

(The Lockheed Electra NP3A is an intermediate altitude (1500 to 25,000 feet) aircraft)

Instruments	Spectrum	Format	Resolution	Field of View	Status
RS-7 infrared imager	8 to 14 μ	70mm film	--	--	Operational
Dual-channel infrared imager	0.3 to 5.5 μ 8.0 to 14 μ	70mm film Magnetic tape	3 feet at 1000 ft alt	80°	1-1-69
Infrared spectrometer	6.5 to 13 μ	Magnetic tape	6 feet at 1000 ft alt	0.4° by 0.4°	--
Infrared radiometer	10 to 12 μ	Magnetic tape	6 feet at 1000 ft alt	0.4° by 0.4°	8-15-68
400-MHz scatterometer	400 MHz	Magnetic tape	3° by 3°	120° by 3°	6-1-68
13.3 GHz scatterometer[b]	13.3 GHz	Magnetic tape	0.01° in flight direction 3° across flight line	120° by 3°	Operational
16.5 GHz side-looking airborne radar (SLAR)	16.5 GHz	Film	50 feet	2° by 56°	8-15-68
Multiple-frequency microwave radiometer	1.4;10.2;22.2;22.3;32.4 GHz	Magnetic tape	--	1.4 GHz - $16^\circ \pm 0.5^\circ$ Others - $5^\circ \pm 0.2^\circ$	12-1-68
RC-8 metric cameras (2)	0.4 to 0.9 μ	9- by 9-in. film	48 lines/mm	74° by 74°	Operational
Modified KA72 camera cluster	0.4 to 1.0 μ	5-in. film	53 lines/mm	74°	8-15-68

[a]Aircraft is presently being equipped as indicated. The estimated operational readiness date for each instrument, as of March 1, is indicated under Status.

[b]13.3 GHz scatterometer can be transferred from Convair 240A aircraft.

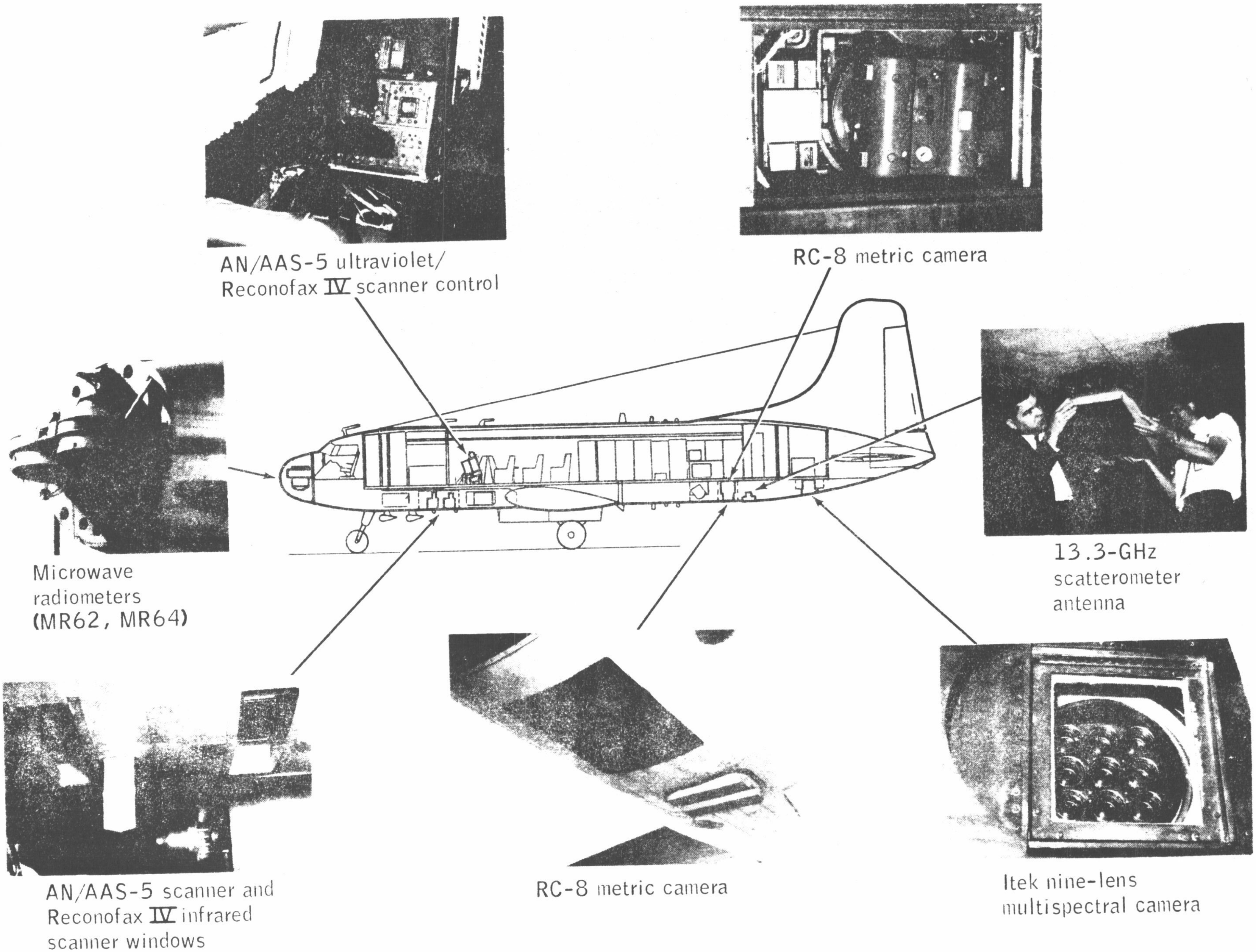
AN/AAS-5 ultraviolet/
Reconofax IV scanner control
RC-8 metric camera
Microwave
radiometers
(MR62, MR64)
13.3-GHz
scatterometer
antenna
AN/AAS-5 scanner and
Reconofax IV infrared
scanner windows
RC-8 metric camera
Itek nine-lens
multispectral camera

TABLE 2

MISSION 78

PARTICIPATING - PERSONNEL

PRIMARY INVESTIGATOR	DR. R. J. P. LYONS JOHN WEAR MARK MEIER	SITES: 19, 3 & 56 SITE : 156 SITE : 40
TEST SITE GEOLOGIST	JACK QUADE	702-329-7238
(SONORA PASS/MONO LAKE)	UNIVERSITY OF NEVADA	702-329-7238
TF/MISSION SCIENTISTS	DR. J. AMSBURY(GEOLOGY) DR. T. BARNETT(SPECT) C. MASON (HYDRO) W. CREA (FORESTRY)	713-483-2781 713-483-4464 713-483-4757 713-483-4611
TF/OPERATIONS MANAGER	N. FOSTER	713-483-3121
TF/MISSION MANAGER	R. H. BAKER	713-483-3811
CC/AIRCRAFT COMMANDER	L. GAVENTA	713-483-7256
EE/SYSTEMS MANAGER	G. FLANNAGAN	713-483-7451
TF/DATA MANAGER	B. EDWARDS	713-483-2094
EE/INSTRUMENTATION	T. SAMPSEL	713-483-2971
ED/COMPUTATION AND ANALYSIS	J. FISHER	713-483-5553
CC/AIRCRAFT OPERATIONS (FRB)	R. CLARK	713-483-7236
CC/AIRCRAFT OPERATIONS (QA)	D. LUCAS	713-483-7654
LEC/IR PALLET OPERATOR	H. COPPEDGE	713-483-7451
LEC/IR SCANNER OPERATOR	J. SEALE	713-483-7451
BL/PHOTOGRAPHER	T. MOORMAN	713-483-7781
BL/PHOTOGRAPHER	J. MONTCRIEF	713-483-7781
EE/IR ENGINEER	H. FITZGERALD	713-483-7421

TABLE 3

MISSION 78 SITE 19 SONORA PASS

PRIORITY/SUBSITE	FLIGHT LENGTH	FLIGHT ALTITUDE A/TERR	FLIGHT ALTITUDE A/S.L.	INSTRUMENTS NEEDED* (IR PALLET, B/W FILMS IN #1 RC8 CAMERA STANDARD)
A. BLACKHAWK (Subsite 1)	7 passes 3 passes 10 @ 3 mi. ea. 30 miles	2000' 8000'	12,000 ft. 18,000 ft.	(IR Pallet on all
B. BROWNBEAR (Subsite 2)	7 passes 3 passes 10 @ 3 mi. ea. 30 miles	2000' 8000'	12,000 ft 18,000 ft.	
C. BLACKHAWK-BROWNBEAR LINE (Subsites 1-2)	2 passes @ 5 mi. ea. 10 miles	8000'	18,000 ft.	+ IR film on one pass.
D. METAMORPHICS	2 passes @ 5 mi. ea. 10 miles	2000'	12,000 ft.	+ IR film on one pass
E. LONGLINE (Sonora "alternate"	1 pass 1 pass 2 @ 9 miles ea. 18 miles	2000' 8000'	12,000 ft 18,000 ft	+ IR film on one pass (8000 ft)
	98 miles			

TOTAL	SONORA PASS	
1968	26 passes	98 miles flight data
(1967)	(38 passes)	(100 miles flight data)

*Camera #1 (RC-8) B/W film 60% stereo overlap, gyro stabilized.

NOTE: Wherever possible, pass directly over lakes, preferably at start.

TABLE 4

MISSION 78 SITE 3 MONO LAKE

PRIORITY/SUBSITE	FLIGHT LENGTH	FLIGHT ALTITUDE A/TERR.	A/S.L.	INSTRUMENTS NEEDED* (IR PALLET, B/W FILM IN #1 RC 8 CAMERA STANDARD)
A. PAOHO IS. (Subsite S1)	3 passes 2 passes 5 @ 2 mi. 10 miles	2500' 5000'	9200ft. 11700ft.	
B. CONWAY GRADE (Subsite S2)	5 passes @3 mi. 15 miles	2000'	12000ft.	
C. BODIE (Subsite S3)	1 passes 1 passes 2 passes @ 2 1/2 mi. 5 miles	2000' 4000'	11000ft. 13000ft.	+IR film on high altitude
D. MONO CRATERS (Subsites S4)	1 pass @ 6 mi. 6 miles	2000'	11000ft.	+IR film
E. GRANT LAKE-AEOLIAN BUTTES (Subsite 5)	1 pass @ 4 mi. 4 miles	4000'	11000ft.	+IR film
F. BLACK BUTTE (Subsite S6)	1 pass @ 2 mi. 1 pass @ 2 mi. 4 miles	2500' 5000'	9000ft. 12000ft.	+IR film
G. LINE P1 (LeeVining N)	1 pass @ 10 mi. 10 miles	4500'	11500ft.	+IR film +RS7 Scanner
H. LINE P2 (Copper Mtns.)	1 pass @ 6 mi. 6 miles	2000'	11500ft.	+IR film + RS7 Scanner
I. LINE P3	1 pass @ 6 mi. 6 miles	4500'	11500ft.	+IR film + RS7 Scanner
J. LINE P4	1 pass @ 10 mi. 10 miles	4500'	11500ft.	+IR film + RS7 Scanner

TOTALS:	MONO LAKE	
1968	26 passes	76 line miles data
(1967)	(38 passes)	(80 100 line miles data)

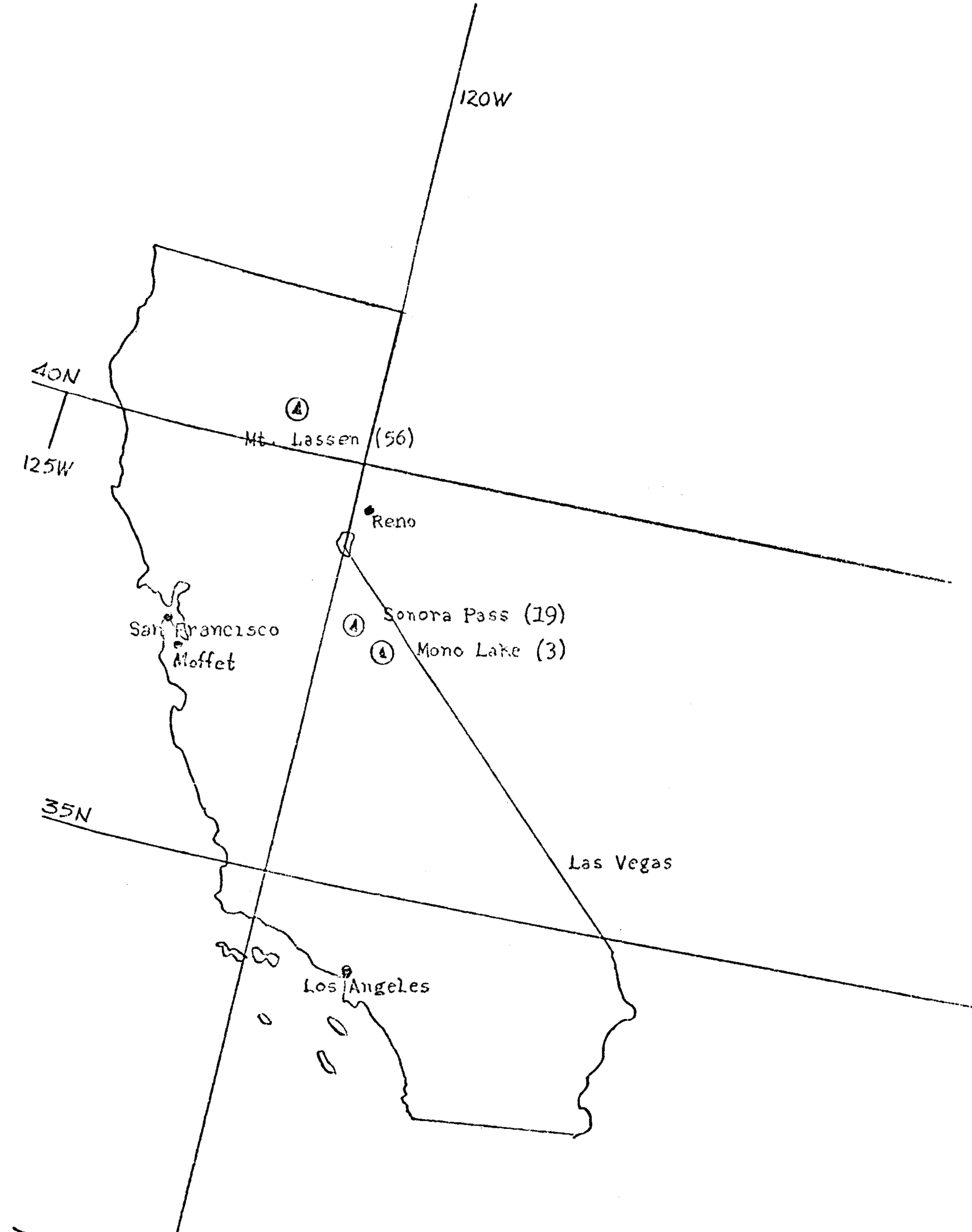

FIGURE 1 - INDEX MAP

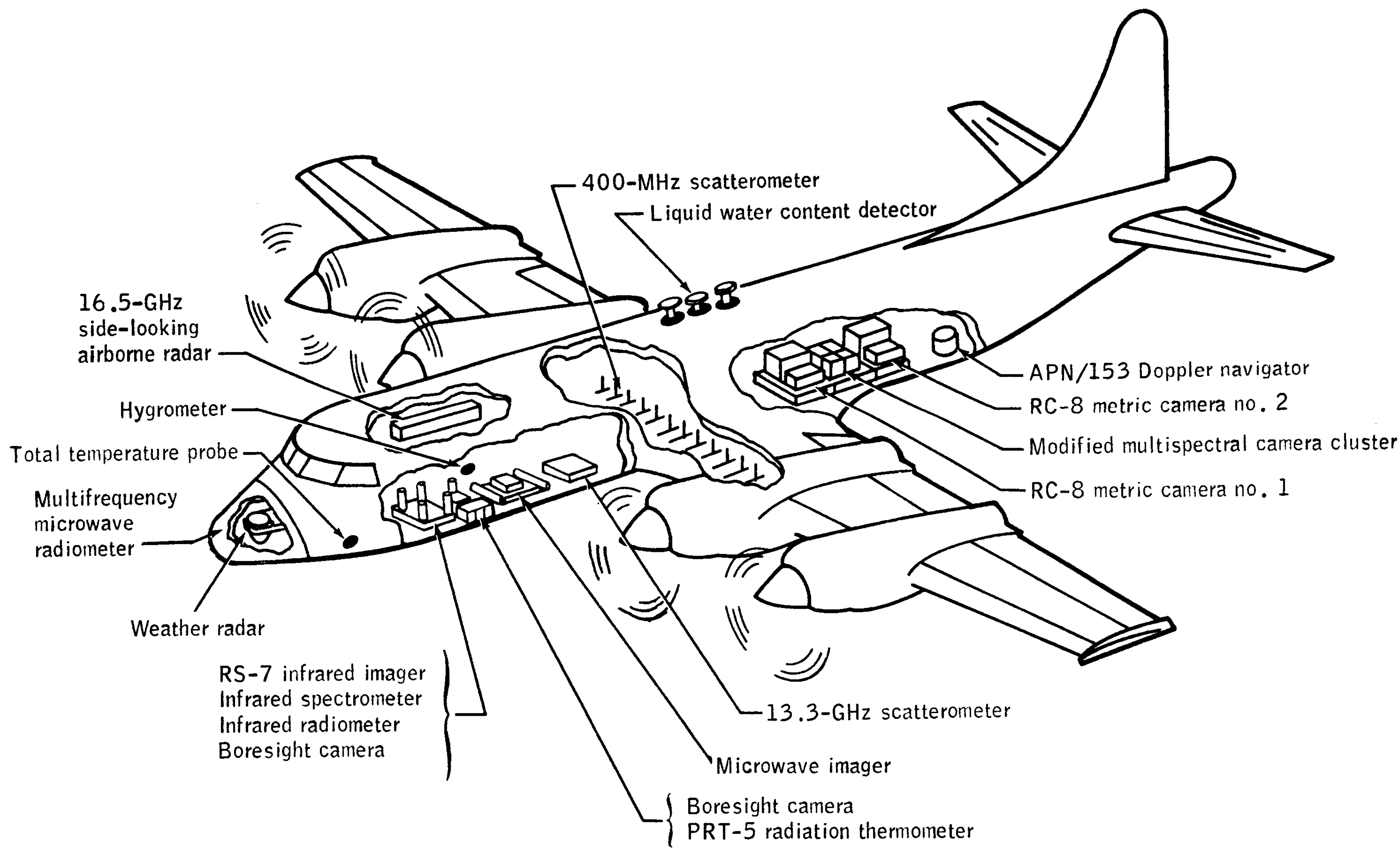

FIGURE 2 - NASA - MSC P3A AIRCRAFT

FRONT OF AIRCRAFT

COMMANDER	CO-PILOT
NAVIGATOR	
PRINCIPAL INVESTIGATOR	MISSION MANAGER
INSTRUMENTATION MANAGER	OBSERVER 1
IR ENGINEER	OBSERVER 2
IR PALLET OPERATOR	
IR SCANNER OPERATOR	PHOTOGRAPHER - IR
	PHOTOGRAPHER - BW
DATA MANAGER	PHOTOGRAPHER - MULTISPECTRAL

REAR OF AIRCRAFT

FIGURE 3 - LOCATION OF PARTICIPATING PERSONNEL IN THE P3A AIRCRAFT

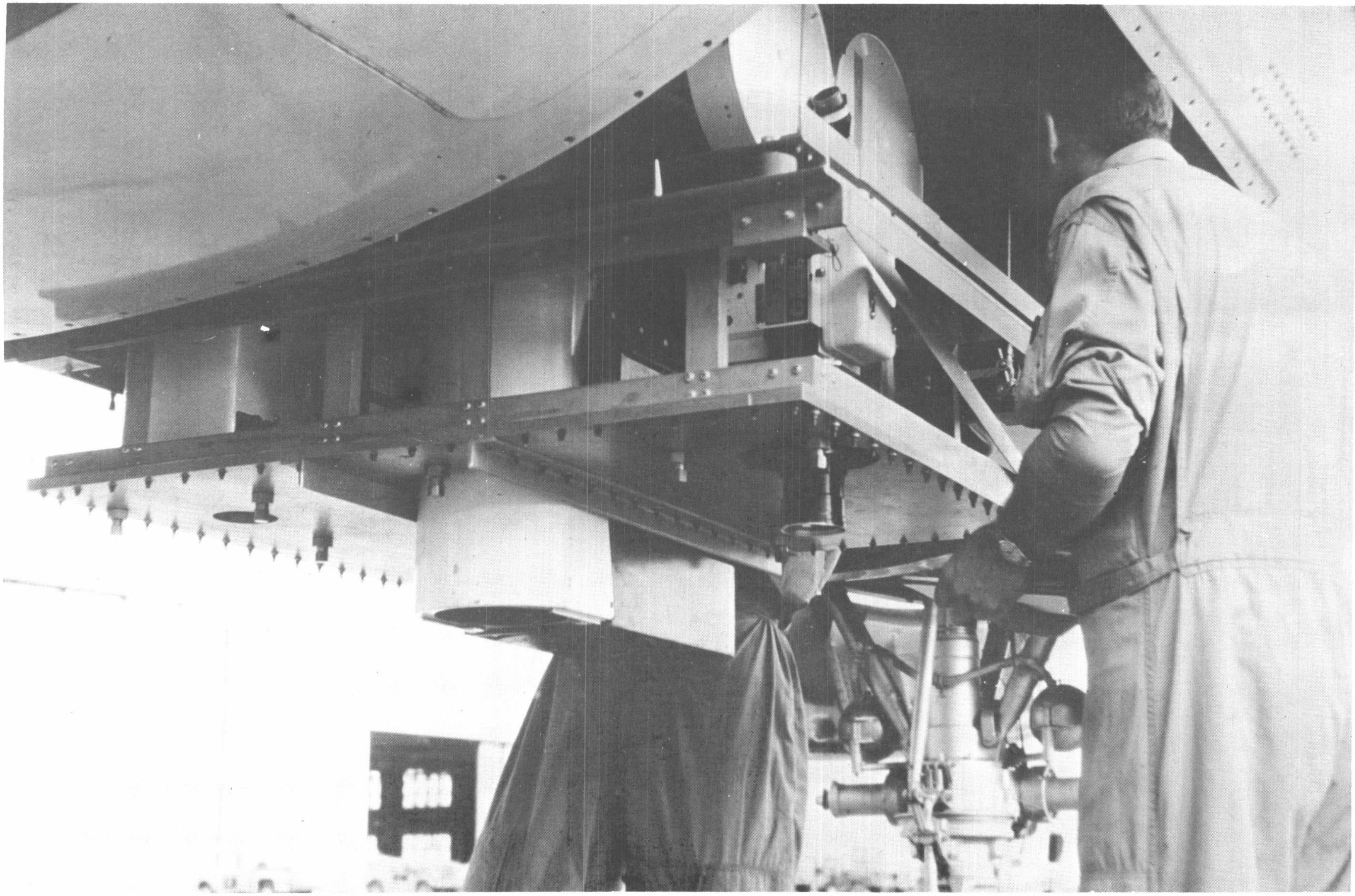

FIGURE 4 - IR PALLET BEING INSTALLED IN AIRCRAFT

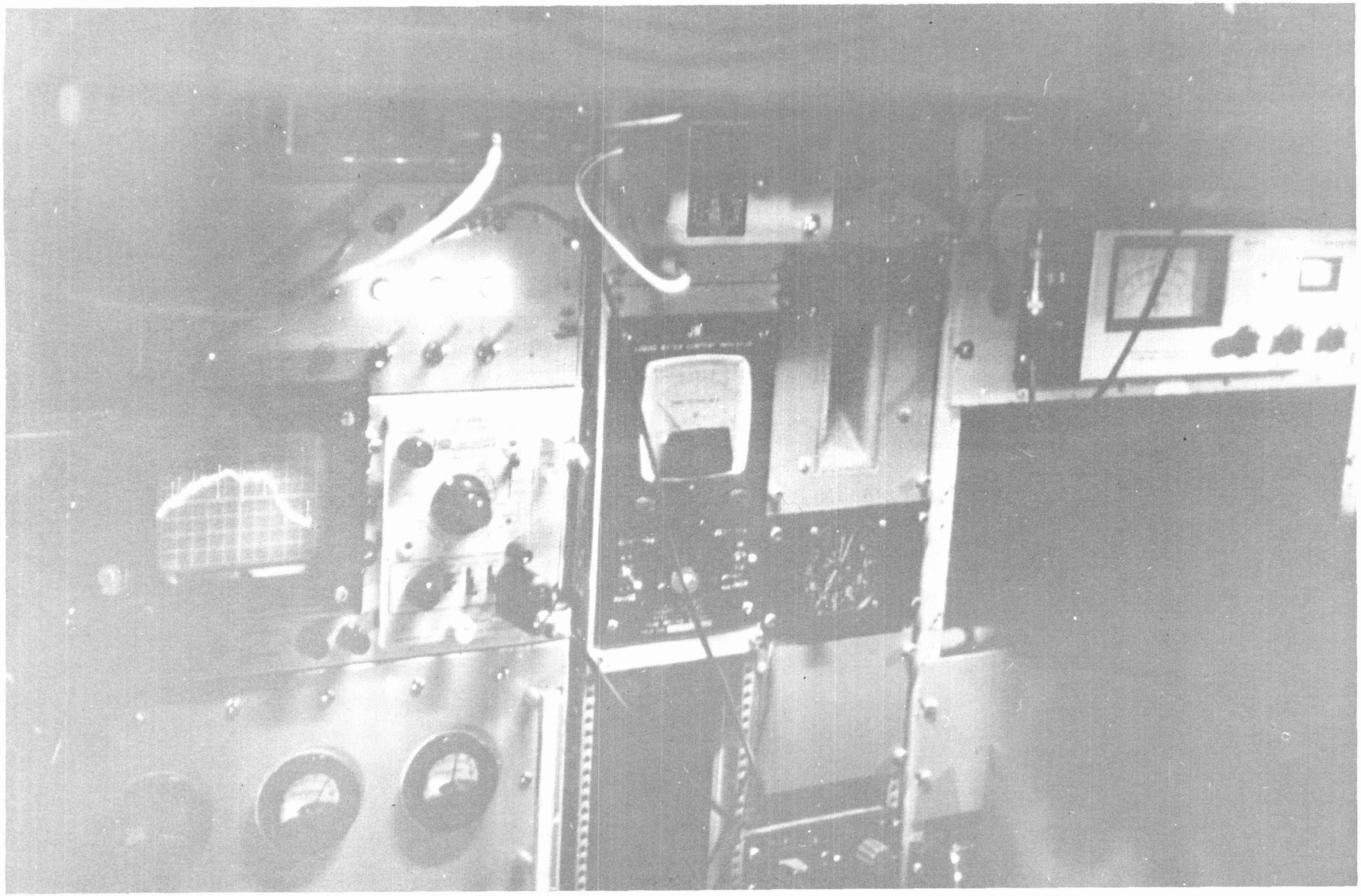

FIGURE 5 - IR PALLET MONITORING EQUIPMENT INSIDE P3A AIRCRAFT DURING INFLIGHT OPERATION

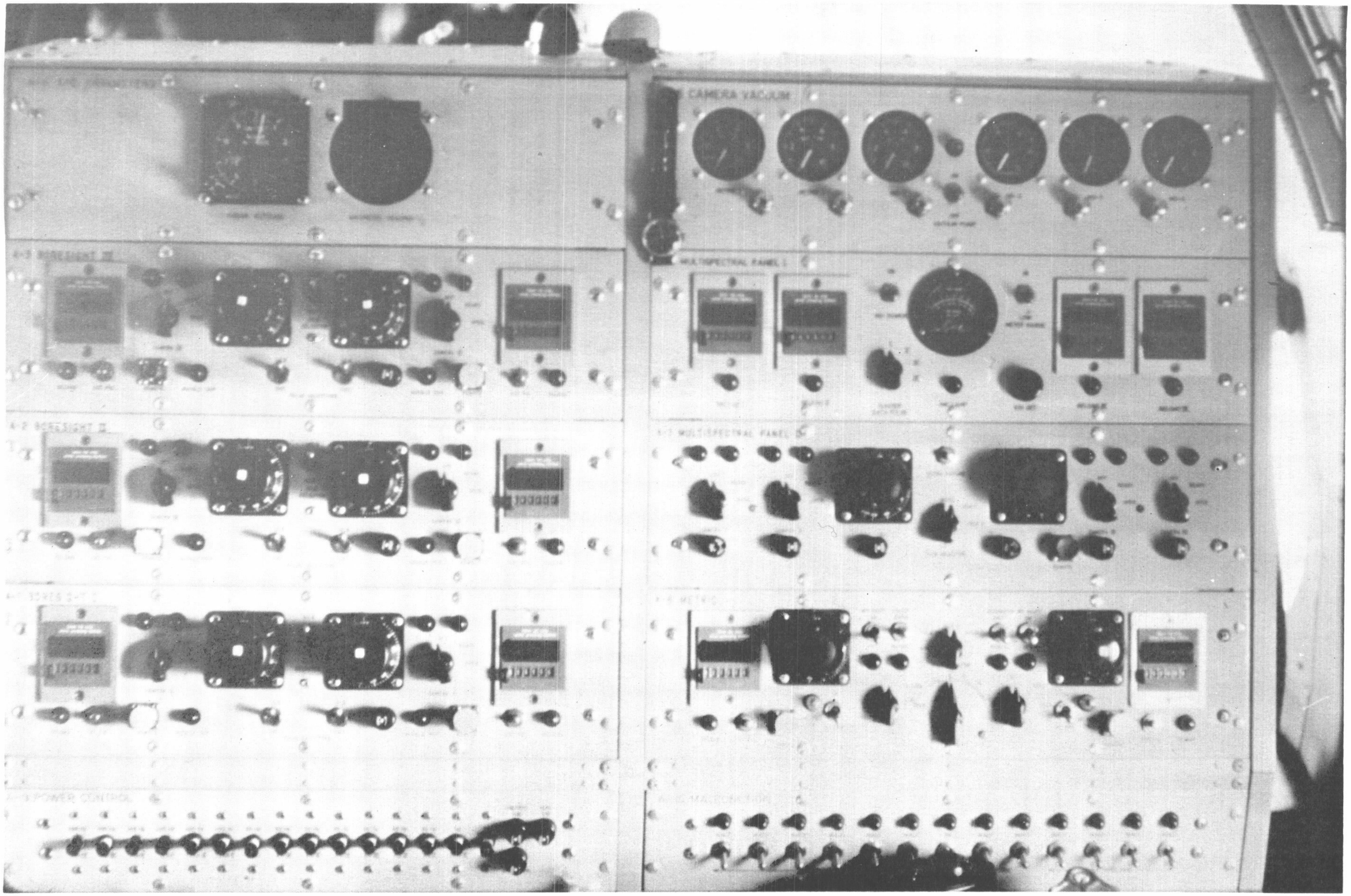

FIGURE 6 - CAMERA MONITORING PANEL INSIDE P3A AIRCRAFT

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